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Foliar Application of Seaweed Extract and Micronutrients on Plant Growth and Yield of Strawberry (*Fragaria* X Annanassa Duch) CV. Winter Dawn: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

The study investigates the potential benefits of integrating seaweed extracts and micronutrients into the cultivation practices of strawberries to enhance overall plant performance and fruit production. Seaweed extracts are known to contain bioactive compounds, including plant growth regulators,

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amino acids, and minerals, which have been reported to positively influence various physiological processes in plants. Additionally, micronutrients play a crucial role in the plant's metabolic activities, and deficiencies can lead to reduced growth and yield. The synergistic effects of seaweed extract and micronutrients present an intriguing avenue for improving the overall health and productivity of strawberry crops. The review summarizes the findings from recent studies, assessing the impact of foliar application of seaweed extracts and micronutrients on strawberry plants. Improvements in growth parameters, nutrient uptake, and yield attributes were observed. Furthermore, the review concluded the potential use of various seaweed extract and micronutrients in strawberry cultivation for significant advantages.

Keywords: Seaweed extract, micronutrients, metabolic activities, foliar application.

1. INTRODUCTION

The strawberry, scientifically known as Fragaria × ananassa, is a hybrid species that belongs to the Rosaceae family. The optimum temperature for the growth of perennial strawberry lies between 7°C and 13°C at night and 22°C to 25°C during the day [1].It is a cultivated garden strawberry that originated from a cross between the Virginia strawberry (*Fragaria virginiana*) and the Chilean strawberry (*Fragaria chiloensis*).The genus Fragaria includes several species that produce strawberries, and they are collectively referred to as strawberries [2].

The cultivation of strawberries, particularly the Winter Dawn variety, is of significant agricultural interest due to the economic importance and widespread consumption of this fruit.

Due to the regress loss of firm texture, they have a shorter shelf life. Low calcium levels have a significant impact on all of the cell wall characteristics of fruit that includes, cell wall thickness, strength of cell wall, turgor, and pectate lyase enzyme [3]. The foliar application of seaweed extract and micronutrients has gained attention as a potential strategy to enhance plant growth, improve nutrient uptake, and ultimately increase crop yield [4].

Seaweeds are macroscopic algae growing in the marine and shallow coastal waters and on rocky shores. Seaweed extract are the biostimulants, that accounts for more than 33 % of the global market and by 2022, its value reached to 894 million euros [5,6]. Seaweed extract is known for its rich content of bioactive compounds, such as auxins, cytokines, and other growth-promoting substances [7].These compounds have been reported to positively influence various physiological processes in plants, including seed germination, root development, and flowering.

Micronutrients, essential elements required by plants in small quantities, play a crucial role in various metabolic processes [8].Their deficiency can significantly impact plant growth and yield. The foliar application of micronutrients aims to address such deficiencies and optimize the overall nutritional status of the plants.

The study reviews existing literature, synthesizes research findings, and critically evaluates the effectiveness of foliar application of seaweed extract and micronutrients on strawberry plants. It explores the physiological mechanisms underlying the observed effects, considering factors such as nutrient absorption, photosynthesis, and stress tolerance [9].

2. EFFECT OF SEAWEED EXTRACT ON PLANT GROWTH OF STRAWBERRY

Around 844 species of seaweeds have been reported from Indian seas, out of which 434 species are Red Algae, 194 species are Brown Algae, and 216 species are Green Algae [10]. Some of the red algae species are- *Gelidiella acerosa, Gracilaria edulis, G. crassa, G. foliifera and G. verrucosa* are used to manufacture agar. Brown Algae includes *Sargassum spp., Turbinaria spp*. and *Cystoseira trinodis* which are used for the production of alginates and liquid seaweed fertilizer [11]. Seaweed extracts, derived from various types of seaweed or algae, have been studied for their potential benefits on plant growth and development. Seaweed extract, in its different types and methods of application, has been a catalyst for plant growth and productivity. In the study, Masny *et al.,* [12] observed better quality of strawberry with the application of seaweed (Kelpak SL and Goemar BM86®) with three treatments (0, 0.5 and 1 ml.L-1) sprayed in leaves.

Taha [13] observed the influence of spraying three seaweed extracts (Algren, Soluamine, Mannarine) in two types of Strawberry (Hapil and Kaiser's sampling). It is summarized that spraying cv. Kaiser's sampling with seaweed

(Algren) stimulates an increase in the total chlorophyll content and also enhance the ratio of pollen viability, whereas spraying extracts Soluamine has boosted flower in each plant more than negative controls, as for the cv. Hapil when using Algren extract, there was an increase in dry weight of shoots and leaf area and important superiority of crown diameter. It also promotes an increase in the number of flowers in each plant. [14] uses variable concentrations of seaweed extract (SWE) viz, 0.75 ml L-1, 1.0 ml L-1, and 1.25 ml L-1 which were applied at the pre-flowering stage (PFS) or Fruit set stages (FSS) or both the stages (PSS and FSS). The study revealed that the foliar spray of seaweed extract at pre-flowering and fruit set increased the blooming characteristics and runner production in strawberry. While the specific effects can vary depending on the type of seaweed extract, concentration, and application method, here are some general potential benefits of using seaweed extract on strawberry plants:

Nutrient Content: Seaweed extracts are rich in various essential nutrients, including micronutrients; trace elements, and growth-promoting hormones [15].These can contribute to improved plant nutrition, leading to enhanced growth and development.

Stress Tolerance: Seaweed extracts may help plants cope with environmental stress, such as drought, salinity, or temperature extremes. This stress tolerance can be especially beneficial for plants growing in challenging conditions [17].

Root Development: Seaweed extracts have been reported to stimulate root development. Healthy and well-developed roots are essential for nutrient uptake, water absorption, and overall plant health [18]. Improved root systems can contribute to increased plant vigor.

Yield and Fruit Quality: Some studies suggest that the application of seaweed extracts can positively impact fruit yield and quality on strawberry.. This may include factors such as fruit size, color, and taste [19].

Table 1. Nutrient content of seaweed extract

Nutrients	Contents
Nitrogen (N)	0.18%
Phosphorus (P2O5)	0.48%
Potassium (K2O)	1.89%
Calcium	0.11%
Magnesium	0.01%
Sodium	0.13%
Iron	256.0 ppm
Zinc	11.87 ppm
Copper	15.62 ppm
Manganese	13.12 ppm

Source: [16]

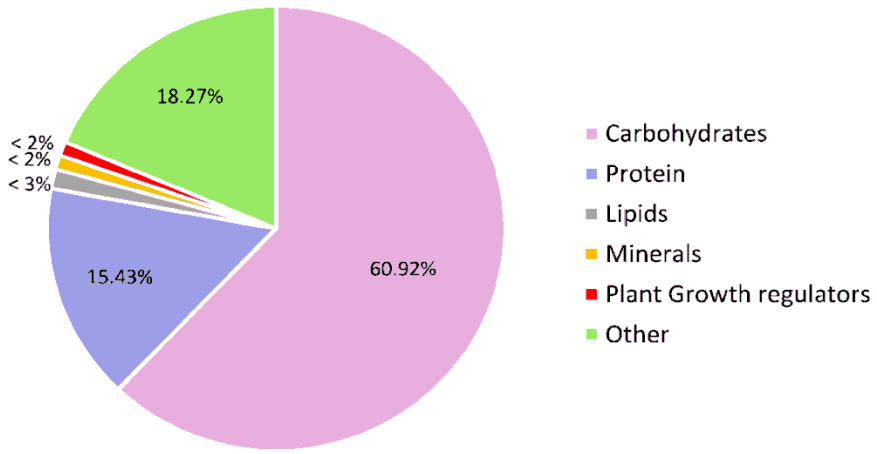

Fig. 1. Estimated composition of seaweed extracts shown through pie-chart

Disease Resistance: Seaweed extracts have been investigated for their potential to enhance a plant's resistance to certain diseases [20]. In the study, Jayaraj et al [21]. concluded in their research that, the seaweed namely *Ascophyllum nodosum* is able to decrease the fungal disease severity caused by *Alternaria radicina* and *Botrytis cinerea* in carrot. Also effective result has been observed with extract of Sargassum wightii (seaweed), to control leaf spot disease which is caused by *Pseudomonas syringae* of the medicinal plant *Gymnema sylvestre* [22]. Bianco et. al. [23] evaluated extracts of the algae Canistrocarpus cervicornis (Ochrophyta, Phaeophyceae), Laurencia dendroidea, Hypnea musciformis (Rhodophyta) and Chaetomorpha antennina (Chlorophyta) and concluded that concentrations of 300 ppm presented mortality above 50% against larvae of the fourth stage of *Aedes aegypti* .While not a replacement for proper disease management practices, seaweed extracts may contribute to a plant's overall health and resilience.

Bio-stimulant Effects: Seaweed extracts are considered bio-stimulants, meaning they can enhance various physiological processes in strawberry plants [24].This can include increased photosynthesis, nutrient absorption, and hormonal regulation.

Environmental Sustainability: Seaweed extracts are often promoted for their environmentally friendly nature. They are derived from renewable marine resources and are generally considered to have a low environmental impact [25].

3. EFFECT OF MICRONUTRIENTS ON PLANT GROWTH AND YIELD OF STRAWBERRY

Micronutrients play a crucial role in the growth and development of plants, including strawberries (*Fragaria x ananassa Duch*). While macronutrients such as nitrogen, phosphorus, and potassium are required in larger quantities, micronutrients are essential in smaller amounts for various physiological functions. Chaturvedi *et al.* [26]. demonstrated that the application of zinc sulphate at 0.4% and ferrous sulphate at 0.2% in strawberry increased its growth, yield and quality attributes. Abdollahi *et al.,* [27] reported that boron in concentration of 150 and 300 mg per liter increased number of leaves and leaf area, although some quality variables such as vitamin C and total soluble solids were reduced. Similarly, Yadav *et al,* [28]. concluded in the experiment with strawberry cv. winter dawn that the maximum fruit diameter (4.20cm) was reported in their treatment T14-Boric acid 0.4% and Maximum fruit weight, fresh weight (28.09g) as well as dry weight (2.05g) were found in treatment T16- Zinc sulphate 0.4%.

Here are some effects of micronutrients on the growth and yield of strawberries:

Iron (Fe): Chlorophyll Formation: Iron is a key component of chlorophyll, the green pigment responsible for photosynthesis. A sufficient supply of iron promotes healthy leaf development and overall plant vigor.

Flower and Fruit Development in strawberry, Iron is also involved in the formation of flowers and fruits, contributing to reproductive success and yield of strawberry [29].

Manganese (Mn): Enzyme Activation: Manganese activates several enzymes involved in photosynthesis, respiration, and nitrogen metabolism. This positively impacts energy production and nutrient assimilation of strawberry [30].

Disease Resistance: Manganese plays a role in plant defense mechanisms, helping the plant resist certain diseases.

Zinc (Zn): Enzyme Activation: Zinc is a cofactor for many enzymes involved in various metabolic processes, including auxin synthesis. Adequate zinc levels contribute to proper hormone balance and overall plant growth of strawberry [31].

Fruit Formation: Zinc is essential for fruit development and maturation.

Copper (Cu): Enzyme Activation: Copper is involved in the activation of enzymes related to photosynthesis and lignin formation. Lignin strengthens cell walls, providing structural support to the plant [32].

Reproductive Processes: Copper is crucial for pollen formation and fertilization, influencing fruit set and yield of strawberry.

Boron (B): Cell Wall Formation: Boron is essential for cell wall formation and stability. It influences the transport of sugars and the development of meristematic tissues.

Flower and Fruit Development: Boron is particularly important during flowering and fruiting stages, impacting seed and fruit set of strawberry [33].

Molybdenum (Mo): Nitrogen Metabolism: Molybdenum is essential for nitrogen metabolism, particularly in the conversion of nitrate to ammonia. This process is crucial for protein synthesis and overall plant growth of strawberry [34].

Chlorine (Cl): Osmotic Regulation: While chlorine is not considered an essential micronutrient for strawberry plants [35].It plays a role in osmotic regulation and stomata function.

4. CONCLUSION

In conclusion, the reviewed literature suggests that foliar application of seaweed extract and micronutrients can be a valuable strategy for enhancing the growth and yield of Winter Dawn strawberry cultivars. However, further research and field trials are needed to fine-tune application methods and better understand the underlying mechanisms for optimal results in different growing conditions.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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